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Basic design guidance developed from extensive reevaluation of facilities is presented for use by experienced architects and engineers. The contents cover electrical utilization considerations such as interior electric power, lighting, communication, signal and fire alarm systems; emergency electric power systems; roadway, protective and area lighting; and criteria for earthquake areas design.

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DECEMBER 1979

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ELECTRICAL ENGINEERING

ELECTRICAL UTILIZATION SYSTEMS

DESIGN MANUAL-4.4

DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
200 STOVALL STREET
ALEXANDRIA, VA. 22332

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ABSTRACT

Basic design guidance developed from extensive reevaluation of facilities is presented for use by experienced architects and engineers. The contents cover electrical utilization considerations such as interior electric power, lighting, communication, signal and fire alarm systems; emergency electric power systems; roadway, protective and area lighting; and criteria for earthquake areas design.

A

FOREWORD

This design manual is one of a series developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command, other Government agencies, and the private sector. This manual uses to the maximum extent feasible, national professional society, association, and institute standards in accordance with NAVFACENGCOM policy. Deviations from these criteria should not be made without prior approval of NAVFACENGCOM Headquarters (Code 04).

Design cannot remain static any more than can the naval functions it serves or the technologies it uses. Accordingly, recommendations for im provement are encouraged from within the Navy and from the private sector and should be furnished to NAVFACENGCOM Headquarters, (Code 04). As the design manuals are revised they are being restructured. A chapter or a combination of chapters will be issued as a separate design manual for ready reference to specific criteria.

This publication is certified as an official publication of the Naval Facilities Engineering Command and has been reviewed and approved in accordance with the SECNAVINST 5600.16A.

D. G. Iselin

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Commander
Naval Facilities Engineering Command

ELECTRICAL ENGINEERING DESIGN MANUALS

DM No.	Superseded Chapters in Basic DM-4	Title
4.1	1	PRELIMINARY DESIGN CONSIDERATIONS
4.2	2	POWER DISTRIBUTION SYSTEMS
4.3	3	SWITCHGEAR AND RELAYING
4.4	4	ELECTRICAL UTILIZATION SYSTEMS
4.5	-	FOUR-HUNDRED HERTZ GENERATION AND DISTRIBUTION SYSTEMS
4.6	5	LIGHTNING AND CATHODIC PROTECTION
4.7	*7	WIRE COMMUNICATION AND SIGNAL SYSTEMS

*Chapter 6, Electromagnetic Interference Suppression, of the basic DM-4 will be incorporated in a new design manual, DM-12, Electronic Facilities Engineering.

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ELECTRIC UTILIZATION SYSTEMS

Section 1. CODES AND REQUIREMENTS

1. SCOPE. This manual presents data and considerations that are necessary for the proper design of interior electric power, lighting, communication, signal and fire alarm systems; emergency electric power systems; roadway, protective and area lighting; and criteria for earthquake areas design.

2. CANCELLATION. This manual of electric utilization systems, NAVFAC DM-4.4, cancels and supersedes Chapter Four, NAVFAC DM-4, Electrical Engineering, of March 1974, and Change 1 of August 1974.

3. RELATED CRITERIA. For criteria related to electric lization systems but appearing elsewhere in the Design Manual se , see the following sources:

Subject	Source
Electric Power Distribution Systems	.FAC DM-4.2
Equipment rooms	
Grounding	
Poles	
Roadway lighting distribution, overhead and underground	
Electric Switchgear and Relaying	NAVFAC DM-4.3
High-impedance busway	
Low-voltage switchgear	
Panel and switchboard locations	
Electronic Facilities Engineering	NAVFAC DM-12
Fire Protection Engineering	NAVFAC DM-8
Fire alarm systems	
Mechanical Engineering	NAVFAC DM-3
Emergency generators	
Magnetic motor starter types	
Motor control centers	
Preliminary Electrical Design Considerations	NAVFAC DM-4.1
Uninterruptible power systems	
Typhoon and Tropical Areas Engineering	NAVFAC DM-11
Wire Communication, and Signal Systems	NAVFAC DM-4.7

4. POLICIES. Design shall conform to the following:

a. DOD Policies. See Department of Defense, Construction Criteria Manual, DOD 4270.1-M.

b. Local Codes. Although the Federal Government is not required to conform to city or district building codes for property within Federal Government ownership lines, local codes should be considered. The design and installation of interior lighting, electric power facilities, and roadway lighting systems should conform, as far as practicable, with adjoining community regulations and standards.

c. National Codes. NFPA 70, the National Electrical Code (NEC) and ANSI C2, the National Electrical Safety Code (NESC) establish minimum standards of design and installation practices, and their recommendations must be followed. Electrical materials and equipment should conform to the standards of the Underwriters' Laboratories, Inc., or other recognized testing agencies or laboratories.

d. Design Analysis. The design analysis covering electrical systems shall be made in accordance with good design procedures based on the conservation of energy and shall show all calculations used in determining capacities of such systems. Methods and tabulations used in sizing conductors, conduit, protective devices, and other equipment needed to complete a system, which require other than routine methods, shall be included. All calculations shall be clearly shown so that any changes that become necessary due to resiting or revisions during construction can be made efficiently. When tables used in the design are taken from publications, the title, source, and date of the publication shall be plainly indicated. The model number and manufacturer of each major piece of equipment on which space allocation was determined shall be indicated in the analysis. Equipment of at least three manufacturers shall be capable of being installed, serviced, maintained, and replaced in the space available.

e. Specifications. The design criteria in this chapter shall conform to the requirements of NAVFAC Type Specifications TS-16301, Underground Electrical Work; TS-16302, Overhead Electrical Work; TS-16335 Transformers, Substations and Switchgear, Exterior; TS-16402, Interior Wiring Systems; TS-16462, Pad Mounted Transformers; TS-16465, Interior Substations; and TS-16475, Transformers, Substations and Switchgear, Interior.

f. Requirements for Physically Handicapped. For pertinent information on making buildings and facilities accessible to, and usable by, physically handicapped personnel, see ANSI A117.1, Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped.

g. Architectural Considerations. Exterior and interior exposed electrical items shall be shown or indicated as such, and their use shall be coordinated with the architectural design. For electronic facilities, criteria in DM-12 shall apply.

h. OSHA Requirements. Provide all safety features in accordance with the Occupational Safety and Health Act (OSHA).

Section 2. INTERIOR ELECTRIC POWER AND LIGHTING SYSTEMS

1. SERVICE. Service wires to interior electric systems should be as short as possible. During installation of overhead services, consider possible future underground service installation. If feasible, install empty conduits from service rooms to points 5 feet (1.5 meters) beyond building walls.

a. Service Equipment. Locate service equipment at service entrance point. Use circuit breakers, according to the characteristics indicated in low-voltage switchgear (see DM-4.3). Circuit breakers cannot single-phase, do not require fuse replacement, and are more difficult to modify so as to carry currents greater than originally intended. Fused switching devices should be used where special considerations necessitate their use. Such a situation may result when circuit breakers alone cannot provide adequate fault duty and must be coordinated with current-limiting fuses. Select the most economical devices consistent with short circuit and normal current requirements. Services with three-phase motor loads should include protective devices which will open all three phases immediately upon the failure of any one phase, to prevent damage to the motors.

b. Service Conductors. The use of more than two conductors in parallel should be discouraged. Either busway or a medium-voltage distribution system should make such usage only necessary for exceptional conditions, such as on piers where ships' services require large low-voltage currents. In such cases, consider providing individual conductors with limiter lugs having fuses which protect the size of cable used. All conductors serving the same load shall be of the same sizes and lengths. Where located in raceways, each phase conductor and a neutral, if used, shall be installed in each raceway.

c. Metering. All facilities on naval property, regardless of the operating agency, shall be provided with a revenue metering installation ahead of the main disconnecting device. In addition, where required for future use, submetering provisions shall also be provided for energy consuming mechanical/ electrical systems such as lighting and heating, ventilating and air conditioning, and for multiple tenants within a building.

d. Short Circuit Considerations. Service protective devices must be able to clear any fault on secondary systems without damage. Where service conductors are connected to low-voltage network systems, the service protective devices and the entire utilization system may be subjected to large short circuit currents.

e. Methods of Short Circuit Duty Reduction. Where available short circuit currents reach values above ratings of ordinary protective devices it may prove economical to use a short circuit duty reducing means instead of special switchgear. Select short circuit reducing equipment from the following:

(1) Current Limiting Fuses. Use current limiting fuses for general reduction of short circuit duty. Find the maximum let-through current from fuse characteristic curves. The effective value of this current will determine the short circuit rating of equipment placed on the load side of current limiting fuses.

(2) Other Methods. These methods are available but their use should be restricted in accordance with the following:

(a) High-impedance busways. High-impedance busways can be used for small reductions where current-limiting fuses are not economical. Such use is not recommended (see DM-4.3).

(b) Reactors. Use reactors to reduce short circuit duty to existing equipment, or elsewhere where current-limiting fuses are not easily installed. Such installations have many limitations, and the designer must exercise exceptional judgement in selecting components based on the determination of the following factors:

(i) Current carrying capacity.

(ii) Maximum symmetrical short circuit current available at the connecting point.

(iii) Bracing required to withstand mechanical stresses produced by such currents.

(iv) Minimum impedance per phase.

f. Service Equipment Rooms. Utilities shall be accessible, and equipment rooms shall be sized to provide sufficient space for proper maintenance. If electrical equipment is located in a combination electrical-mechanical equipment room, adequate space for electrical equipment must be reserved. For access, ventilation, emergency lighting, and coordination with other trades, see DM-4.2.

g. Service Grounding. Connect the neutral of a system to ground at one point and provide for grounding connection at the incoming main secondary disconnecting device. Grounding conductors should be sized in accordance with the NEC with the grounding electrode having a maximum resistance to ground of 25 ohms (see DM-4.2).

2. WIRING SYSTEMS. For locations of switchboards, power panelboards, and lighting panelboards in relation to the electric circuits, see DM-4.3.

a. Standard Voltages. Voltages selected should be the highest level consistent with the type of load served. In the selection of system voltages, consider load magnitudes, distances to load centers, availability of utilization devices at voltages under consideration, safety, standards, and codes. The utilization voltage levels are as follows:

(1) A 208Y/120-volt system is usually most economical when the major portion, 60 percent or more, of the load served consists of 120-volt utilization equipment and lighting and the average length of feeders is less than 200 feet (60 meters).

(2) Where large motors constitute a major portion of a mixed load, or in buildings having one or more electric services aggregating 600 amperes or more and where more than 50 percent of the load may be served by a 480Y/277-volt system, this service voltage shall be supplied. The lighting system shall be designed to operate at 277 volts. All three-phase motors shall be served at 480 volts. Small appliance loads, convenience outlets, and other loads requiring lower voltages shall be served from dry-type transformer stepping down 480 volts to 208Y/120 volts.

(3) Motors 1/2 horsepower and larger shall be three-phase type, unless three-phase service is not available. In that case, motors 1/2 horsepower and larger shall be operated at the higher phase voltage rather than the phase-to-neutral voltage.

b. Voltage Spread. Determine the voltage spreads in the system, taking into account the effects of overvoltages and undervoltages in the load types. After the voltage spread has been determined, distribute the total voltage drop among the elements of a system in the most economical way. In any facility, the combined feeder and branch circuit voltage drop shall not exceed the limits imposed by the NEC.

c. Power Factor. Generally utilization equipment having an inductive reactance load component shall have a power factor of not less than 90 percent lagging under rated load conditions. When the power factor of the utilization equipment is less, power factor correcting devices shall be switched with the utilization equipment to provide a power factor of not less than 90 percent in accordance with DOD 4270.1M. Fluorescent lighting devices should be specified to have a power factor of not less than 95 percent lagging.

d. Wire and Cable. Select types of insulation, in conformity with NAVFAC TS-16402, according to duty and location. See the NEC for insulation types, operating temperatures, voltage classes, and applications. Do not exceed values of allowable current-carrying capacities listed in the NEC. Branch circuits and feeder conductors shall be sized at 125 percent of full load ampacity to minimize I^2R losses. Do not pyramid the conductor size, if future capacity sizing adequately provides this allowance. For installation in abnormal ambient temperatures, and for more than three conductors in a raceway, apply derating factors as directed by the NEC.

e. Raceways. Metal raceways shall not be embedded in concrete that contains coral aggregate or is made with salt or brackish water.

For these cases, use nonmetallic raceways. Select raceways from the following types:

(1) Electrical Metallic Tubing. Use electrical metallic tubing (EMT) to enclose branch circuit conductors, up to 1/0 AWG (53.5 square millimeters) maximum size, for exposed runs in dry locations, hung ceilings, hollow block walls, and furred spaces. Electrical metallic tubing shall not be installed underground, outdoors, or encased in concrete.

(2) Flexible Steel Conduit. Use flexible steel conduit for applications similar to those in which EMT is employed, and for connection to vibrating equipment, between junction boxes and recessed lighting fixtures, between expansion joints in exposed runs, and for short connections.

(3) Rigid Steel Conduits. Use rigid steel conduits for runs concealed in concrete and in wet and hazardous locations.

(4) Aluminum Conduit. Use aluminum conduit for applications similar to those used for steel conduits, but do not install this type by direct burial in alkaline locations or encase in concrete. Use for high-frequency circuits where steel would cause magnetic problems. Do not use in electromagnetically sensitive areas.

(5) Rigid Nonmetallic Conduit. Use rigid nonmetallic conduit where permitted by the NEC.

(6) Intermediate Metal Conduits. Intermediate metal conduit (IMC) can be used in lieu of rigid conduit.

(7) Wireways. Use wireways only for exposed work. Do not fill wireways over 20 percent of their cross sectional areas. For special conditions, see the NEC.

(8) Electrified Floor Systems. Use in administrative areas where the distance between walls is more than 20 feet (6 meters) between permanent partitions. Use cellular floor systems with trench header preferably. Underfloor duct systems may be used where cellular floor decking is not feasible, either structurally or economically. Power, signaling, and telephone systems shall each be run in separate cells and through compartmented trenches or junction boxes. Locate electrified cells to permit rearrangement of partitions and room layouts without revisions to underfloor systems, other than relocation of outlets and wiring. Locate electrified cells so that no electrified cells shall occur at partitions or on module lines.

(a) Cellular floor system. Nominal size of each electrified cell should be 9 square inches (60 square centimeters). Where smaller cells can be installed structurally, consider using two cells for telephone circuits. Telephone circuits should provide for use of call director telephones. Normally, a thirty-line call director telephone has a 100 pair, 24 AWG (.205 mm^2) line connection requiring a minimum conduit size of 1-1/4 inches (3.175 centimeters). Usually, if the cell size is adequate for call director telephone circuits it is more than adequate for electric power and signal circuits. For trench header capacity, provide 2 square inches (13 square centimeters) per 1,000 square feet (100 square meters) of office space for each system in small buildings. For buildings having a gross administrative space in excess of 50,000 square feet (5,000 square meters) increase 2 square inches (13 square centimeters) to 4 square inches (26 square centimeters) for telephone circuits and decrease to 1-1/2 square inches (10 square centimeters) for electric power and signal circuits. Trench headers should not be run in corridors unless absolutely necessary. Use FCGS 16115, Underfloor Raceway System (Cellular Steel Floor) for material.

(b) Underfloor duct system. Size feeder ducts on same basis as trench headers. To avoid congestion in feeder ducts, provide parallel conduit feeders, usually 1-1/4 inches (3.175 centimeters), from panelboards or closets to load areas. Select cell sizes based on wiring requirements providing for future area applications and load growth. Use the following sizes; (i) minimum cross sectional area of ducts shall be 3.3 square inches (21 square centimeters), (ii) maximum spacing between feeder ducts shall be 50 feet (15 meters), and (iii) minimum concrete cover over ducts shall be 3/4 inch (1.905 centimeters). Insert and junction sizes should be based on the required wiring capacity and minimum bending radius of the largest wire or cable to be installed. Use FCGS 16113, Underfloor Duct System for material.

f. Hazardous Locations. Conform with provisions of the NEC where the equipment and associated wiring is installed within hazardous areas.

g. Special Areas. Install weatherproof, dustproof, dust-ignition proof, dusttight, and watertight equipment, and associated wiring in accordance with the NEC.

3. ELECTRIC POWER SYSTEMS. Characteristics, types, and information for all motors and controllers are included under Power Plants in DM-3.

a. Electric Power Distribution to Motors

(1) Voltage Level. To determine the most economical voltages for electric power systems find the break-even points between distribution and switchgear costs. See standard voltages and raceway systems under paragraph 2. of this section.

(2) Electric Power Feeders. In general, feeders serving electric power circuits shall carry only electric power loads.

Determine feeder sizes from the following:

(a) Capacity. Current carrying capacities of conductors serving motors, under normal running conditions, and under intermittent duties should be considered.

(b) Voltage drop. Continuous currents should not produce voltage drops that will reduce motor torques below minimum required values; nor should starting currents of the largest motor produce voltage dips of such magnitudes as to actuate the undervoltage releases, or to disengage smaller motors in a system. In any event, do not exceed maximum voltage drops of the NEC.

(c) Short Circuits. Motors and associated equipment must be protected against damaging short circuit currents. Limit maximum fault currents at mains of the grouped protective equipment. Determine maximum short circuit let-through currents, using the aforementioned methods for reduction of short circuit duty. Consider the effects of: (i) duration of inrush currents through protective devices and (ii) excessive voltage drops in reactors.

b. Motor Controlled Requirements. Motor controllers (starters) should be provided for motors larger than 1/8 horsepower. For motors of 1/8 horsepower or less, see the NEC requirements.

(1) Manual Type. Manual starters may be used for motors up to the maximum horsepower ratings shown in Table 1; but only when the

TABLE 1

Standard Manual Controller Ratings for 600 Volts and Below[1]

NEMA size	Voltage (volts)	Maximum horsepower rating	
		Single-phase	Three-phase
M-0	115	1	-
	200	-	3
	230	2	3
	460[2]	-	5
M-1	115	2	-
	200	-	7 1/2
	230	3	7 1/2
	460	-	10
M-IP	115	3	-
	200	-	-
	230	5	-
	460	-	-

[1]From NEMA ICS-1970.
[2]Values for 575 volts are the same as shown for 460 volts.

motor is not controlled by automatic devices, unless all automatic devices have adequate horsepower ratings.

(2) Magnetic Type. Magnetic controllers shall be full-voltage-across-the-line starting except where reduced-voltage starting is required by the capacity of the system which supplies the motor. Such a case is where the transformer kilovolt-amperes are not much greater than the motor horsepower or where the motor starts many times an hour. For a comparison of system types, see Table 9-29 in DM-3. Magnetic starters shall be of the ratings shown in Table 2.

(a) Reduced voltage. Use reduced voltage starters where full starting motor current would result in more than a 30 percent transient voltage dip. The starting kilovolt-amperes (SkVA), dependent upon motor type, may range from 250 to 1,200 percent of the motor's full load kilovolt-amperes, with 600 percent an average value. Curves of maximum voltage dip values resulting from motor-starting for a generator plant bus are shown in Figure 1. These curves are typical for generators having a rotative speed of 600 to 1,800 rpm and which utilize exciters rotating at 1,200 rpm or higher when the generators are already loaded to 50 percent of their rating. Maximum voltage dip values for a unit substation secondary bus (with unlimited short circuit capacity available from the primary system) are also shown in Figure 1. A comparison of these curves shows that the voltage dip on starting is much greater on the generator bus than on the unit substation secondary bus; this is because generators have a much higher reactance than do transformers. Figure 2 shows an example of the difference in voltage dip dependent upon whether the motor is supplied by the unit substation or the emergency generator. For other situations, see Industrial Power Systems Handbook by Beeman for calculations of voltage drops due to motor starting.

(b) Motor control centers. Generally, motor control centers should be NEMA class I, type B. Selection of motor control centers and types is covered in DM-3.

c. Receptacles. Receptacles for installation on 15- and 20-ampere branch circuits should be of the grounding type with the grounding contacts effectively grounded.

(1) Locking Type. Use locking type receptacles where positive engagement of plug is required or where a strain on the portable cord can be anticipated.

(2) Enclosures. Enclosures shall be UL approved for damp locations, UL approved for wet locations, UL enclosed and gasketed, or UL approved explosionproof type, as required, in damp, wet or hazardous locations (see the NEC).

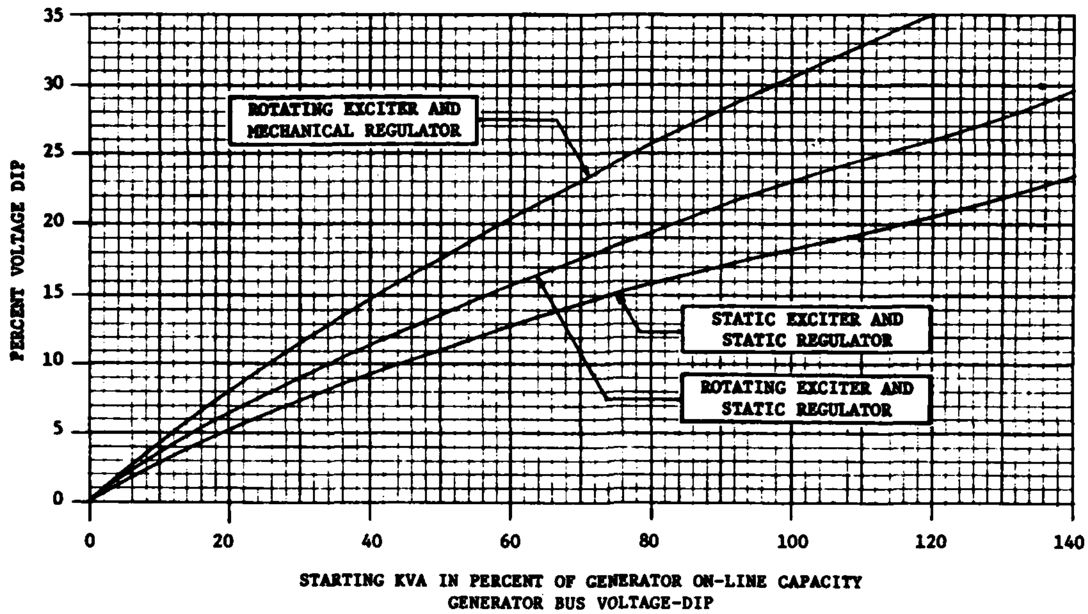
4. LIGHTING. The design of interior lighting systems and lighting intensities shall be in accordance with DOD 4270.1-M and the IES Lighting Handbook. For lighting levels, luminaire types for special areas, and particular requirements, consult criteria for the specific facility.

TABLE 2

Standard Magnetic Controller Ratings for 600 Volts and Below[1]

NEMA size	Amperes[2]	Voltage (volts)	Maximum horsepower rating		Maximum horsepower rating for plugging service[3]	
			Single-phase	Three-phase	Single-phase	Three-phase
00 . .	9	115	1/3	-	-	-
		200	-	1 1/2	-	-
		230	1	1 1/2	-	-
		460[4]	-	2	-	-
0 . .	18	115	1	-	1/2	-
		200	-	3	-	1 1/2
		230	2	3	1	1 1/2
		460	-	5	-	2
1 . .	27	115	2	-	1	-
		200	-	7 1/2	-	3
		230	3	7 1/2	2	3
		460	-	10	-	5
2 . .	45	115	3	-	2	-
		200	-	10	-	7 1/2
		230	7 1/2	15	5	10
		460	-	25	-	15
3 . .	90	200	-	25	-	15
		230	-	30	-	20
		460	-	50	-	30
4 . .	135	200	-	40	-	25
		230	-	50	-	30
		460	-	100	-	60
5 . .	270	200	-	75	-	60
		230	-	100	-	75
		460	-	200	-	150
6 . .	540	200	-	150	-	125
		230	-	200	-	150
		460	-	400	-	300
7 . .	810	200	-	-	-	-
		230	-	300	-	-
		460	-	600	-	-
8 . .	1215	200	-	-	-	-
		230	-	450	-	-
		460	-	900	-	-
9 . .	2250	200	-	-	-	-
		230	-	800	-	-
		460	-	1600	-	-

[1]From NEMA ICS-1970.
[2]Continuous current rating for enclosed general purpose controllers.
[3]An example is plug stop or jogging (inching duty) which requires continuous operations with more than five openings per minute.
[4]Values for 575 volts are the same as shown for 460 volts.



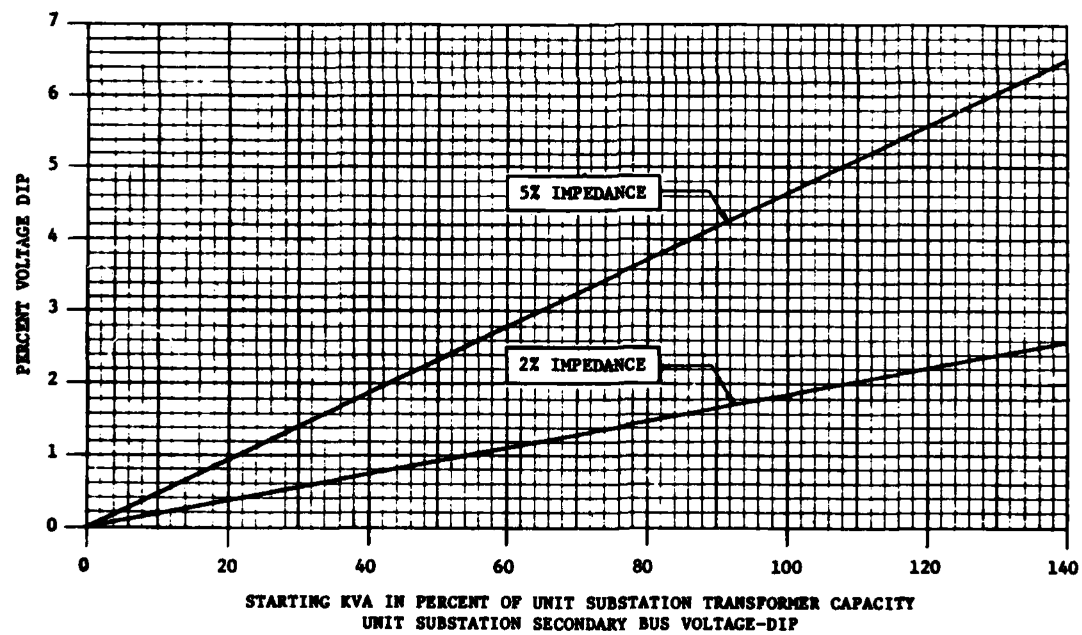


FIGURE 1

Motor-Starting Voltage-Dips

a. Architectural Requirements. Lighting systems shall be coordinated with building designs for aesthetic and decorative effects, within the limits of visibility, visual comfort, economics and energy conservation.

b. Design Analysis. Lighting calculations shall adhere to the established procedures of the IES as set forth in the IES Lighting Handbook and IES Recommended Practices.

(1) Usual Illumination Analyses. For general applications, average illumination may be calculated using room cavity ratios and luminaire coefficients of utilization (zonal-cavity method).

(2) Special Computer Analyses. Where comprehensive lighting studies are required to determine alternative lighting sources for large multiroomed buildings or average to minimum illumination (point-by-point method), it may be necessary to run a computer analysis using NAVFAC programs.

(a) LUMEN II program. The lumen II program can analyze the following quantities:

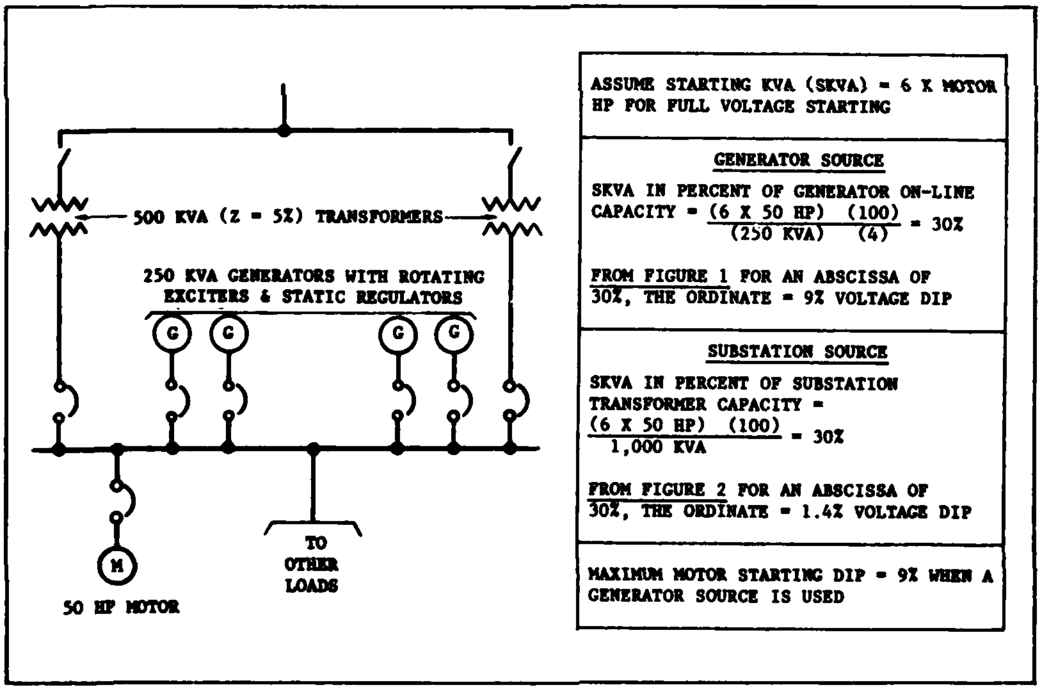


FIGURE 2

Voltage-Dip on a Bus from Full-Voltage Starting

(i) Illumination.

(ii) Equivalent sphere illumination (ESI).

(iii) Visual comfort probability (VCP).

(iv) Wall luminances.

(b) E-6801 (LIGHT) program. The E-6801 program is suitable for determining illumination for large multiroomed buildings.

(c) RELAMP program. Economics (luminous flux per uniform annual cost) for any lighting system may be optimized using the RELAMP program.

(d) SELFDOC System. A listing and description of available NAVFAC computer programs can be found in the computer aided design (CAD) SELFDOC system.

c. Visibility. Luminaire placement and candlepower distribution shall be chosen to minimize veiling reflections. Veiling reflections reduce the contrast of the components of the task and made seeing the task more difficult. Light coming over the workers' shoulders or from the sides generally produces better visibility than light coming from the front of the workers (offending zone). An analysis of ESI can be made when the specifics of the task are known, along with a knowledge of the task background and luminaire candlepower distribution and location in relation to the task. Generally such detailed analyses will be unnecessary unless specifically required.

d. Visual Comfort. Luminaire placement, candlepower distribution, and luminance ratios shall be chosen to minimize discomfort glare. Discomfort glare is produced by high brightness within the field of view. Visual comfort may be determined by making a VCP analysis, or by requiring that the luminaire have a minimum VCP of 70 and also meet the other luminance requirements for visual comfort required in the IES handbook.

e. Economics For a large building, a comprehensive lighting study may be required from an economic viewpoint to aid in the selection of lighting sources and sizes of lamps. When studying alternatives, consider the initial investment, life span of the installation, energy expense, cost of replacing light sources at the end of effective life, and cleaning cost. Life-cycle costs shall be calculated in accordance with NAVFAC P-442, Economic Analysis Handbook. Selection of the most economical alternative shall be based on the maximum luminous flux (lumens) per uniform annual cost.

f. Energy Conservation. Means shall be provided to reduce general lighting operating intensities in accordance with the criteria of DOD 4270.1-M. These methods, fully covered by DOD

4270.1-M, include reduction by manually turning off selected luminaires using multiple switching circuits, and time or photoelectric control. Multiple switching circuits can utilize alternative switching of luminaires, inboard-outboard switching of four-tube fluorescent luminaires, local switching for task control, perimeter lighting control adjacent to glassed areas so as to take advantage of daylight, and use of SCR dimmers where economically feasible. Other methods include use of lower wattage lamps, or provision of ceiling construction which easily accommodates luminaire relocation. Energy conservation methods shall apply not only to administrative areas, but to all areas with illumination levels of 30 footcandles (30 dekalux) and above.

g. Lighting Source. When selecting lighting sources for interior systems the most important aspect is the characteristics of the source; however, also consider stroboscopic effect, radio interference, chromacity, and color rendition.

(1) Characteristics. Characteristics of light sources are shown in Table 3. The light source used should be the most energy conserving consistent with usage.

(2) Recommended Sources for Specific Task Areas. Table 4 shows recommended usage for specific task areas.

(3) Additional Considerations.

(a) Color rendition. Unless there is a need for color matching, color rendition need not be considered. Where the color rendition of high-pressure sodium (HPS) lamps is unacceptable, metal halide lamps should be used in preference to mercury vapor lamps, if the available lamp wattage is suitable for the area.

(b) Chromacity. Chromacity within areas should always be considered. Once the adaptation has been made to a lighting system of any color temperature, user acceptance is greater when another color source is not introduced. Thus in a shop area using HPS lamps, the small office and toilet spaces commonly associated with the area should also use HPS lamps. If fluorescent lamps must be used in such an area, they should be the warm-white type. The surrounding color environment (painted walls, ceiling, and floor) shall be compatible with the chromacity of the selected source.

(c) Radio frequency interference. Fluorescent fixtures can be provided with shielded enclosures and filtered ballasts for use in areas where radio frequency interference (see DM-12) must be minimized (for example in an Instrument Calibration Shielded Room).

(d) Stroboscopic effect. Except for high speed photography and other rare situations, stroboscopic effect generally will

TABLE 3

Characteristics of Light Sources

Characteristics	Light sources				
	High intensity discharge[1]			Fluorescent	Incandescent
	HPS	Metal halide	Mercury vapor		
Luminous efficacy (lumens/watt)[2]	70–125	65–100	30–50	55–65	15–25
Lumen maintenance	Good	Fair	Poor	Fair	Good
Lamp life (1,000 hours)	20–24	7.5–15	24	12–20	1–2.5
Lamp life[3] (years)	5–6	2–4	6	3–5	0.25–0.65
Start-up time (minutes)	2–4	3–5	5–7	—	—
Restrike time (minutes)	1	10–15	3–6	—	—
Color rendition	Fair	Good	Fair	Good	Good
Neutral surface color effect	Yellow-pink	White	White	Blue-white	Yellow-white

[1]Incandescent safety lighting is required in large areas or corridors. For areas where HPS fixtures are used, consider installing emergency light sets with a 5 minute time delay off to take care of the restrike or start-up time. For other HID lamps, longer time delays should be provided.
[2]Ballast losses are included.
[3]Computed based on 4,000 burning hours a year.

TABLE 4

Recommended Sources for Specific Task Areas

Task area	Light source
Office areas	Fluorescent[1]
Low-bay shop areas[2]	Fluorescent
Medium-and-high-bay shop areas[3] .	High-pressure sodium[4]

[1]In areas with ceilings 10 feet (3 meters) or lower, use recessed fixtures with prismatic diffusing panels.
[2]Ceilings less than 15 feet (4.5 meters).
[3]Ceilings of 15 feet (4.5 meters) or higher.
[4]In areas with ceilings of less than 25 feet (7.5 meters), use 250 watt or smaller lamps. For ceiling of 25 feet (7.5 meters) or higher, use 400 watt lamps.

not be a problem. Flicker Index has been established by the IES as the measure of stroboscopic effect.

(e) Sources not recommended. Incandescent lighting should not be used, unless no other type of light source is suitable for the special conditions encountered. It has been included in Table 3 only for comparison purposes. Aesthetic reasons are not acceptable for using a source of such low luminous efficacy. Low-pressure sodium lighting is not included as the color is monochromatic and therefore normally is not suitable for general use.

h. Luminaires. In general, luminaires shall conform to NAVFAC TS-16510; Lighting, Interior. Particular effort should be made to reduce the number of luminaire types in any one facility, building, or project, so that the number of spare part replacements required for maintenance will be kept to an absolute minimum. Luminaires, not otherwise covered by this specification, shall be manufacturers' standard types.

(1) Architectural Criteria. The aesth- ics of the luminaire shall be compatible with the area in which it is located.

(2) Classification. Explosion-proof and weatherproof lighting fixtures shall be provided when required for conformance to the NEC. To be suitable for damp location, wet locations, or as an enclosed and gasketed fixture, luminaires must be UL listed as meeting the requirements of UL 57, Electric Lighting Fixtures. To be suitable for hazardous locations, luminaires must be UL listed as meeting the requirements of UL 844, Electric Lighting Fixtures for Use in Hazardous Locations.

(3) Maintenance. Ease of servicing luminaires must be considered in the design process. For lighting fixtures installed in areas where it is difficult and hazardous to relamp fixtures when using ladders (for example, ceiling fixtures in stairwells), consider the use of open bottom fixture enclosures that provide access for relamping with a lamp changer, or mount fixtures on walls.

(4) High Intensity Discharge Lighting. High intensity discharge (HID) lighting should be used to illuminate large, high-bay areas.

(a) Efficiency. Luminaire efficiency should not be less than 70 percent.

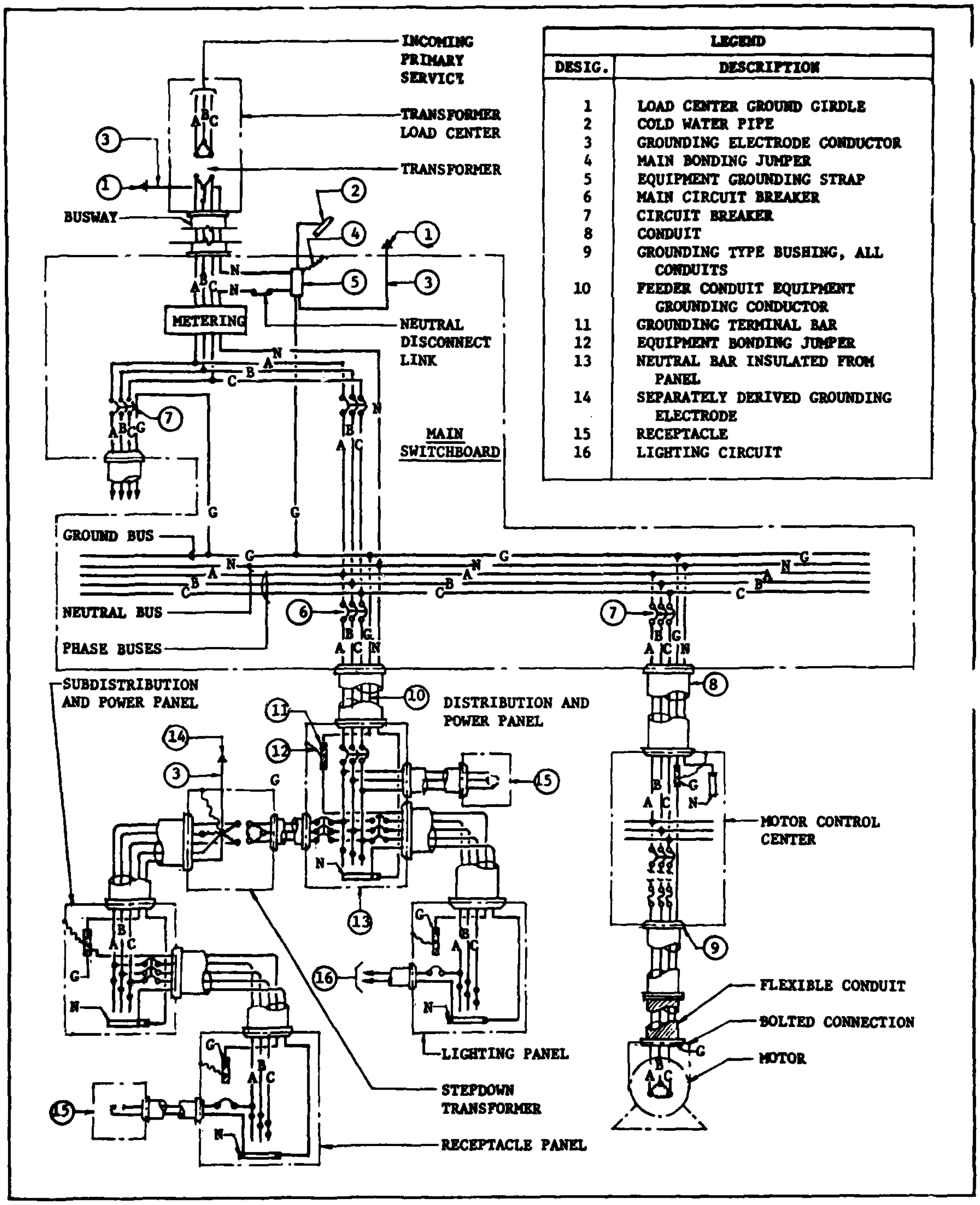
(b) Spacing-to-mounting height (S/MH) ratio. The spacing to mounting height ratio of the luminaire should be not less than 1.3 nor more than 2.0 to provide both uniformity of illumination and sufficient lighting on vertical surfaces. Wattage of lamps should not be increased due to this wide distribution over that indicated in Table 4. Closer spacing will result in an overlap of beam patterns.

In the event of lamp burnout, the loss of illumination will not be as severe, and the vertical lighting will be greater than would be the case from a luminaire with a more concentrating distribution of light. IES requires that the distance from the working plane to the bottom of the luminaires should be used as the mounting height in calculating the S/MH ratio.

(c) Glare. Not more than 10 percent of the light should be emitted from the 60 to 90 degree zone for reasonable freedom from glare. Low brightness diffusers are generally not necessary as HID luminaires are limited to shop areas with ceilings of 15 feet and higher. However, where used in associated small office and toilet spaces with lower ceilings, a diffuser should be used for mounting heights less than 15 feet (4.5 meters) above the finished floor.

(d) Noise ratings. At the present time, no industry noise rating has been given to HID ballasts. For most shop areas, the ambient sound level will mask the ballast hum.

5. GROUNDING. All electrical distribution systems should be provided with a grounded neutral connection. Each voltage level should be grounded independently. Each voltage level grounding point should be located at the power source. Low-voltage systems should be solidly grounded. Figure 3 indicates minimum grounding features. An equipment grounding wire is shown carried from the main switchboard ground bus on to panelboards and motors; however, any type of equipment grounding conductor allowed by the NEC, such as conduit or electrical metallic tubing, is acceptable.



LEGEND	
DESIG.	DESCRIPTION
1	LOAD CENTER GROUND GIRDLE
2	COLD WATER PIPE
3	GROUNDING ELECTRODE CONDUCTOR
4	MAIN BONDING JUMPER
5	EQUIPMENT GROUNDING STRAP
6	MAIN CIRCUIT BREAKER
7	CIRCUIT BREAKER
8	CONDUIT
9	GROUNDING TYPE BUSHING, ALL CONDUITS
10	FEEDER CONDUIT EQUIPMENT GROUNDING CONDUCTOR
11	GROUNDING TERMINAL BAR
12	EQUIPMENT BONDING JUMPER
13	NEUTRAL BAR INSULATED FROM PANEL
14	SEPARATELY DERIVED GROUNDING ELECTRODE
15	RECEPTACLE
16	LIGHTING CIRCUIT

FIGURE 3

Grounding Diagram

Section 3. COMMUNICATION, SIGNAL, AND ALARM SYSTEMS

1. COMMUNICATION SYSTEMS. Communication systems requirements are determined by the specific criteria for various types of facilities; see NAVFAC DM-22 through NAVFAC DM-37.

a. Telephone Systems.

(1) System Selection. From criteria presented in DM-4.7 select a telephone system that will meet the requirements of the projected building.

(2) Empty Conduit System. On drawings, indicate the locations of telephone outlet boxes, cabinets, equipment rooms, batteries, and similar components. Connect all system components by an empty conduit system. Prepare a riser diagram, indicating on it the sizes of conduits in accordance with Table 5. In general a 4-foot by 8-foot by 3/4-inch (1-1/4-meters by 2-1/2-meters by 2 centimeters) wood backboard located in an equipment room is preferable to cabinets. Where cabinets must be used they should be in accordance with Table 6. These tables only apply to single circuit telephones. Where six-button or call director telephones will be installed, minimum conduit sizes should be 3/4 inch (19.05 mm) for six-button units and 1-1/4 inch (31.75 mm) for call director units. Backboards should be installed for such systems and the local Telephone Company should be consulted to be sure that the backboard size or closet area is adequate.

TABLE 5

Conduit Sizes for Telephone Systems

Location	Number of pairs	Conduit size in inches (mm)
From outlet to backboard or cabinet . .	1	1/2 (12.7)
	2-3	3/4 (19.05)
	4-5	1 (25.4)
	6-8	1-1/4 (31.75)
Between backboards or cabinets.	To 25	1-1/4 (31.75)
	50	1-1/2 (38.1)
	100	2 (50.8)
	200	2-1/2 (63.5)
	400	3 (76.2)
	600	3 (76.2)
	900	4 (101.6)
	1,200	4 (101.6)

b. Intercommunications and Sound Systems. Use the telephone system criteria of this section and DM-4.7. Provide a separate raceway for each system. Locate the devices on plans and show the number of wires on riser diagrams.

TABLE 6

Cabinet Sizes for Telephone Systems

Number of circuits	Cabinet size[1] in inches (centimeters) W x H x D
10	10 x 12 x 4 (25 x 30 x 10)
15	10 x 16 x 4 (25 x 40 x 10)
25	12 x 24 x 4 (30 x 60 x 10)
50	16 x 28 x 5 (40 x 70 x 15)
100	24 x 32 x 5 (60 x 80 x 15)
150	36 x 36 x 5 (90 x 90 x 15)
200	30 x 54 x 5 (75 x 140 x 15)
250	30 x 54 x 5 (75 x 140 x 15)
300	36 x 60 x 8 (90 x 150 x 20)
400	48 x 60 x 8 (120 x 150 x 20)

[1]The minimum thickness of metal cabinets should conform to the NEC.

c. <u>FM and TV Master Antenna, Closed Circuit TV, and Central Dictation Systems</u>. Use the telephone system criteria of this section (see DM-4.7). Provide a separate raceway for each system. Locate the devices on plans, and show the number of wires on the riser diagram.

2. SIGNAL SYSTEMS. The signal systems requirements for a specific facility are determined by its specific criteria. See DM-22 through DM-37. Locate the devices on plans, and show the number of wires on the riser diagram.

a. <u>Nurse Call and Doctor Paging and Register Systems</u>. Provide nurse call and doctor paging and register systems in accordance with the criteria in DM-4.7.

b. <u>Clock and Programming Systems</u>. Select a clock and programming system from the criteria in DM-4.7 and show the locations of equipment on drawings.

3. ALARM SYSTEMS. The alarm system requirements for various types of facilities are determined by their criteria (see DM-22 through DM-37). Ascertain system requirements from NAVFACENGCOM or other authority, to insure integration with associated systems and operating procedures. Provide a separate raceway for each alarm system if combined systems are not provided. Locate the devices on the plans, and show the number of wires on the riser diagram. Provide auxiliary emergency power for all alarm systems.

a. Fire Alarm Systems. For information on fire alarm systems, see DM-8.

b. Watchman Tour Systems. Select electric or manual systems from criteria in DM-4.7 and consider a combination of fire alarm systems with report systems for the watchman.

c. Disaster Alarm Systems. See DM-4.7.

4. REMOTE CONTROL AND MONITORING SYSTEMS. Safer and more economical operation can often be obtained by installing well designed systems to bring operations for an entire section of a facility under the control of a Duty Dispatcher at the Central Supervisory Control Station. Such systems shall include any necessary protective shutdown devices and alarms to alert the dispatcher of abnormal situations as soon as they develop. These systems shall also make it possible for the dispatcher to obtain any readings (such as pressure and tank gages) and to operate equipment (such as pumps and valves), using suitable communication links as described in DM-4.7. Examples of two remote control and monitoring systems are shown in NAVFAC Drawing No. 1311355, Control System for Naval Fuel Depot, and NAVFAC Drawing No. 1311356, Control System for Interterminal Pipeline.

Section 4. EMERGENCY POWER SYSTEMS

1. CRITERIA. Design of emergency power systems should be in accordance with criteria in this section and IEEE 446, Recommended Practice for Emergency and Standby Power Systems.

2. ESSENTIAL LOADS AND MAGNITUDES. From criteria for specific buildings, determine essential loads and magnitudes. Provide these loads with continuous energy. Selection of emergency power depends on capacities and required degrees of continuity.

3. MINIMUM ESSENTIAL OPERATING ELECTRIC LOAD. Estimate the minimum amount of power required to support the essential operation of the activity, under conditions of minimum illumination. Schedule all convenience loads and other loads (such as drydock pumping, electric furnaces, electric welders, and wind tunnels) to avoid concurrent operation of equipment having a large electric power demand.

4. CONNECTION AHEAD OF INCOMING MAIN SECONDARY DISCONNECTING DEVICE. Low-importance emergency loads may be connected ahead of the building incoming main secondary disconnecting device where no emergency power is provided. This permits continued operation in the event of electric faults within the building.

5. ALTERNATE SERVICE. Provide standby service of sufficient capacity to serve all emergency loads.

a. Interconnections. This emergency service shall be electrically remote from the main service.

b. Switches. Provide an automatic throwover switch, with a preferred position connected to the main service.

6. BATTERIES. Batteries may be used as emergency sources of supply for loads served either by alternating current or direct current. Battery selections depend on the use requirements presented below.

a. Individual Emergency Lighting Units. Use individual emergency lighting units for illumination of small areas, such as corridors and stairs.

b. Central Lead-Acid Battery. Use a central lead-acid (calcium type) battery for loads with large inrush current or for general lighting and power application. This type of battery has good electrical qualities, but requires a certain amount of maintenance.

c. Central Nickel-Cadmium Battery. Use a central nickel-cadmium battery for applications where special considerations warrant. These batteries have a high initial cost which does not justify general use.

7. EMERGENCY GENERATOR. For alternating current emergency loads, use

either gasoline, diesel or gas engines, or turbines as prime movers, subject to availability of fuels; use the criteria in DM-3. Depending on the maximum permissible elapsed time between blackout and power restoration, select the engine according to the following requirements.

a. Automatic Starting. Automatic starting units are available to start, accelerate to rated speed, and assume load within 10 seconds. Interruption time will then be 12 to 17 seconds depending on the time delay used to allow for electric power transients.

b. Stored-Energy Starting. Stored-energy starting should be used where only short interruptions of power are permissible, such as for a protective lighting systems. Energy may only be stored in batteries. The use of flywheels, pneumatic pressure vessels, or similar units to provide stored-energy is not acceptable. The stored energy is utilized to provide service during interruption of prime power service and until emergency generation is available. Where no power interruptions and quality power are required see DM-4.1.

c. Location. Units should be located as close to the load as possible. When located outdoors, units shall be mounted in a secure area not subject to weather hazards such as areas lying within a normal flood plain.

Section 5. ROADWAY LIGHTING

1. LIGHTING SYSTEM. A roadway lighting system is necessary at a naval activity for safe movement of vehicles and pedestrians over frequented routes and places. See also DOD 4270.1-M and TS-16530; Lighting, Exterior.

a. Application. Provide roadway lighting for all primary and secondary roadways, piers, and other areas where pedestrian or vehicular traffic occurs.

b. Sources. Use high-pressure sodium lighting as the most energy conserving source which has an acceptable color rendition. The monochromatic color of low pressure sodium is considered unacceptable for general use. For those rare cases where the yellow-pink color of HPS is objectionable, consider the use of metal-halide lamps or mercury vapor lamps, the choice depending upon the influence of lamp life and starting and restrike times. Fluorescent and incandescent lighting should not be used. See Table 3 for characteristics of light sources.

c. Design. Design roadway lighting in accordance with the procedures outlined in ANSI/IES RP-8, Standard Practice for Roadway Lighting.

(1) Roadway and Area Classification. Waterfront and main streets and fitting-out and supply piers shall be classified as local roadways in an intermediate area. Cross streets, residential streets, main streets in secondary naval activities, and fleet landing, hospital, submarine, destroyer, and POL piers, shall be classified as local roadways in a residential area.

(2) Special Considerations. Observe the following precautions:

(a) Light shielding. Roadway lighting units in the vicinity of airfields should be aimed or shielded so that no direct or stray light is emitted above the horizontal to interfere with the nighttime visibility of control tower operators or to be confused with runway navigational lights by incoming pilots.

(b) Physical Interference. Roadway lighting standards along towways, waterfront streets, and where used for general repair, fitting-out, and supply, should not interfere with cranes and other large equipment.

2. WIRING SYSTEMS. To decide what type of connection to use in a roadway lighting system consider characteristics of multiple and series systems.

a. Multiple Systems. This system should be installed with individual lights switched by integral photo-electric devices, except where its use is clearly impractical. This system provides a high power factor; in the event of control failure, only one luminaire or a minor part of the system will black out; and circuits are simple.

b. Series System. This type of system should be used only for short extensions to existing systems where its use is clearly more economical than a multiple system. Series systems require the use of incandescent or mercury vapor light sources, both of which are considered inefficient illumination sources. Since a voltage drop of ten percent is acceptable for exterior lighting feeders, new series systems may be used only where specifically authorized by NAVFACENGCOM. Series systems also have these disadvantages: high cost; low power factor; total blackout possibility in the event of control failure; complex accessory equipment is required including the central constant current transformer and individual film cutouts and isolating transformers which provide a high-voltage hazard; and there can be difficulty in locating faults.

c. Electric Distribution. Electric distribution systems for roadway lighting shall conform to applicable criteria in DM-4.2. The information below applies to each system part.

(1) Lines. Where distribution lines run along entire lengths of roadway lighting circuits, it is economical to run conductors on the same poles, or in ducts, with electric distribution system circuits. Where this situation does not exist, use overhead or underground installations.

(a) Overhead method. The overhead method is usually the most economical way of distribution. For characteristics, see DM-4.2. The minimum size of conductors for overhead distribution shall be No. 6 AWG (13.3 mm^2) medium-hard-drawn copper for Grade B construction, and No. 8 AWG (8.37 mm^2) medium-hard-drawn copper for Grade C construction. Aluminum conductors and other such materials such as copper-clad steel shall have a minimum size equivalent to copper as required by the NESC which also gives grade definitions.

(b) Underground method. Use the underground method for principal streets, piers, and loading areas, to avoid physical interferences and where required for aesthetic purposes such as at certain Housing Areas. Follow the criteria in DM-4.2. Consider direct burial.

(2) Equipment Installation. Depending on location conditions and the type of distribution system, locate equipment in the following manner.

(a) Overhead method. Supply from the secondary of pole mounted transformers. Overhead installation is the least expensive distribution system and may be desirable when electric distribution lines are run on the same poles as roadway lighting units.

(b) Underground method. Supply from building secondary circuits or pad-mounted compartmental type transformers where loads require a lighting service transformer.

d. Control.

(1) Individual Control. Individual control by photoelectric cells should be provided for most multiple systems. This control is independent of dusk and dawn time changes, and failure of a photocell will cause outage of only one fixture. It actuates roadway lighting units whenever daylight reaches preset intensities.

(2) Manual Control. Use manual controls for attended outdoor lighting installations. Manual control is not recommended for large or diversified installations as individual switching becomes complicated, and overall switching does not allow for different area requirements.

(3) Automatic Control. Use automatic controls for nonattended roadway lighting systems where individual control is not appropriate because some or all of the lighting should be turned off before dawn. Provide manual control for each circuit, to override automatic devices for testing and emergency. Select from the following:

(a) Time Switches. Use time switches for installations having pre-determined hours of use. This type of control will require resetting after every electric power failure unless a spring carry-over feature is provided. Use an astronomical dial to compensate automatically for seasonal daylight changes.

(b) Photocells. Special consideration shall be given to the locations of photocell units for group operation. Light sensitive devices shall face north to avoid sunrays, and shall be mounted in a clear and unobstructed area. Time delay devices shall be provided to prevent irregular operation from transient lights or shadows.

(4) Group Control. This control is only to be used for existing series lighting circuits which may use pilot wire, cascading, or carrier frequency where more than one constant current transformer is controlled.

3. AUXILIARY EQUIPMENT. Roadway lighting auxiliary equipment should be chosen as follows:

a. For Multiple Systems. Ballasts are required for HID light sources.

(1) Types. Where available, auto-regulated type ballasts should be selected for use with all HID sources. This type is available for mercury vapor, metal-halide, and the larger HPS lamps. This type is also known as a constant wattage or auto-stabilized ballast. Power factor is high; starting current is less than the operating current; and voltage input range is plus or minus 10 percent. Where auto-regulated ballasts are not yet available, as in the lower wattage HPS types, high power factor auto-transformer or lag-type ballasts should be used.

(2) Interchangeability. Generally a ballast designed for an HPS lamp cannot be used for a metal-halide or mercury vapor lamp and vice versa, except that metal-halide lamps can be used on specifically matched mercury vapor ballasts in rehabilitated areas.

b. For Series Systems.

(1) Constant Current Transformers. The system shall match the ampere rating of the existing constant current transformer supplying the short extension.

(2) Controllers and Protectors. Oil switches, except for interior installations will provide existing control along with protectors to open the primary of a constant current transformer, in the event of an open secondary.

(3) Isolating Transformers. Use isolating transformers to insulate fixtures from high voltages that constitute hazards. Size transformers according to lamp sizes and ampere ratios.

(4) Sockets. Provide special sockets for series systems, with replaceable film cutouts.

(5) Ballasts. Provide integral series ballasts for series mercury vapor lights, except where an entire circuit consists of mercury vapor lamps and the constant current transformer is of a type which permits omitting ballasts on individual lights.

4. POLES. Choose poles from the following types.

a. Wood. Use wood poles where roadway lighting circuits and aerial electric lines are to be run parallel. Mount fixtures on electric distribution poles. Use this method for economical and medium-life span installations. For depth of setting see DM-4.2.

b. Concrete. Use concrete poles for long-life installations; this type has a high initial cost, but requires practically no maintenance, has high strength and is easy to install. Replacement costs, however, are very high. A concrete base is required.

c. Steel. Steel poles also have high strength and long life. Such poles have a lower initial cost but a higher maintenance cost than concrete poles. A concrete base is required.

d. Aluminum. Aluminum poles have higher initial costs than steel but require a minimum amount of maintenance. They require bases similar to those used by steel poles.

Section 6. PROTECTIVE LIGHTING

1. CRITERIA. Protective lighting designs shall be in strict accordance with criteria and intensity levels of illumination stated in OPNAV Instruction 5510.45, U.S. Navy Physical Security Manual. Where OPNAV 5510.45 does not provide criteria, use the data contained in ANSI A85.1, Standard Practice for Protective Lighting.

2. SECURITY LIGHTING. Use either or both of the following methods for security lighting.

a. Boundaries. Light all boundaries and approaches to security areas, to discourage trespassing and to provide early detection.

b. General Illumination. Light areas within property lines for general purpose security.

3. EMERGENCY SOURCE OF SUPPLY. Security lighting must be provided with reliable sources of supply. This requires an alternate or emergency source of supply in addition to the normal supply. For emergency supplies, consider the methods outlined in Section 4 of this manual.

a. Automatic Starting. Use automatic starting when the protective lighting system can tolerate short outage times. Unless the Using Agency so states, an outage time of 90 seconds from loss of illumination until return of full illumination is acceptable.

(1) Incandescent Source. Incandescent lamps will have an outage time of 12 to 17 seconds, when automatic starting is used. They have low luminous efficacy and therefore should only be used where other sources are unavailable or uneconomical.

(2) High Intensity Discharge (HID) Source. HID lamps will have the automatic starting time extended by the amount of time required to restrike the arc. The smallest restrike time, as shown on Table 3, applies to high-pressure sodium (HPS) lamps and is about one minute from a hot lamp state. A lamp should be considered to be hot for up to three minutes after power goes off. Cold-start time of three to four minutes does not apply when auxiliary power is supplied. The use of HPS lamps extends the outage time to 72 seconds, before full illumination is provided as is shown in Figure 4. They have a high luminous efficacy and should be used, except where the type of fixture (such as a searchlight or fresnel lens) is not made for use with HPS lamps.

b. Battery Stored-Energy Starting. Use where interruptions as listed above cannot be tolerated, such as for security lighting of sensitive areas where the Using Agency has determined no restrike time is permitted. Consider supplying alternate HPS lamps from a battery stored-energy source and starting the rest after the generator is started. Another method is to use an emergency generator to supply a back-up quartz-iodide system which is switched off when the HPS system reaches 90 percent of its output. This is expensive because double illumination and emergency generation must be provided.

c. Life Cycle Cost Analysis. Provide a life cycle cost analysis to justify the use of incandescent lamps over HPS lamps only when the 12- to 17-second outage is permissible but a 72-second interruption is not. The life cycle cost analysis should include costs of the methods of providing interim light during restrike time plus costs of a HPS system and compare the total to the costs of an incandescent system.

4. LUMINAIRES. Depending on the application, select protective lighting units for the following.

a. Roadway Lighting. Roadway lighting is covered in Section 5 of this manual.

b. Floodlighting. See floodlighting luminaires covered in Section 7 of this manual. Use floodlighting to illuminate high activity areas and where roadway lighting is inappropriate.

c. Glare Lighting. Glare lighting, to illuminate flat areas free of obstruction for at least 150 feet (45 meters) outside fence limits, provides the best boundary lighting. Fresnel lenses are used mainly to produce this type of glare. Before using, consider the possibility of annoyance to occupants of nearby facilities and the energy inefficiencies of using an incandescent source. Where glare would cause an annoyance to legitimate activities, controlled lighting using roadway or floodlighting luminaries must be utilized.

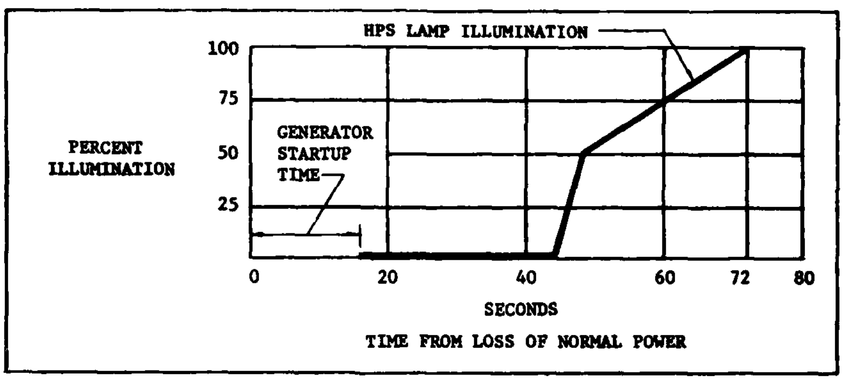


FIGURE 4

HPS Outage Time for Normal-to-Emergency Source Transfer

d. <u>Searchlights</u>. Use incandescent searchlights to supplement protective lighting where increased illumination is required or portable equipment is necessary. Locate searchlights at high elevations, such as guard towers.

5. TARGET LIGHTING. Use target lighting to identify hazardous locations, sites, and equipment requiring immediate recognition. Provide colored lights where contrast with other artificial lighting is needed to signal hazards.

6. PROTECTIVE LIGHTING CONTROL. Provide switching which turns off sections of the protective system lightings, where appropriate. The complete lighting system must be capable of being turned off to provide a total blackout with one operation for sensitive areas. An override of section switching should be considered, where justified by operating or economic considerations, for less sensitive areas.

Section 7. AREA LIGHTING

1. USES. The design of area and sports illumination should be in accordance with DOD 4270.1-M. Provide floodlighting systems for area lighting of storage yards, loading docks, and nightwork areas, to supplement roadway lighting.

2. SOURCES. For selection of lighting sources, see Section 4 of this manual.

3. LUMINAIRES. Choose types according to the floodlighting classifications of the National Electrical Manufacturers Association (NEMA) given in NEMA FA-1, Outdoor Floodlighting Equipment.

a. Enclosures. Use NEMA designations. Select enclosures according to duties, considering initial costs and depreciation charges.

(1) Heavy Duty. Use heavy duty enclosed floodlights for lighting piers, wharves, and areas where corrosion is a factor.

(2) General Purpose. Use general purpose enclosed floodlights where corrosion is not a factor.

(3) Open. Use open floodlights for temporary construction where maintenance is not a factor.

(4) Reflector Lamps. Use reflector lamps for portable and minor installations. This type of floodlighting has low initial, but high maintenance costs. These lamps are not covered by NEMA FA-1.

b. Beam Spread. Determine luminaires according to the beam spread characteristics of NEMA classifications 1 through 6, from spotlights to floodlights.

4. FLOODLIGHTING CALCULATIONS. For the luminaire and source selected, ascertain photometric data including isocandle curves, beam lumens, and coefficient of beam utilization as necessary to calculate lumen distribution coverage.

a. Methods. Select a calculation method from the following:

(1) Beam-Lumen Method. Use the beam-lumen method normally.

(2) Point-by-Point Method. Computer printouts are available from some manufacturers and provide an excellent means for establishing a point-by-point coverage where uniformity ratios must be kept within certain limits.

b. Intensities. Nightwork areas (including piers and loading platforms) may need to maintain an average horizontal illumination level of 10 foot-candles when such criteria has been furnished by the Using Agency. Where no specific criteria is given, use values recommended by IES including maximum to minimum uniformity ratios.

c. Special Considerations. See Section 5 of this Manual, and also investigate the following:

(1) Glare. Select mounting heights that will result in minimum glare unless glare lighting is a requirement for protective lighting.

(2) Coverage. With the beam-lumen method, assure by use of overlapping beam patterns that uniformity and coverage is provided.

5. SPORTS LIGHTING. Floodlighting of sports fields requires special considerations. Avoid stroboscopic effects by connecting light sources to alternating phases. Keep glare to a minimum for both players and spectators. For intensity levels, use recommended practice of IES.

6. WIRING SYSTEM. Use criteria for multiple roadway lighting systems (see Section 5 of this manual). Make an economic study for optimum operating voltages. It may be more economical to increase voltages and use incandescent floodlighting for systems that operate a few hours per year; however, this may violate energy conservation requirements.

Section 8. REQUIREMENTS FOR EARTHQUAKE AREAS

1. CRITERIA. The electrical design and installation shall be in accordance with NAVFAC P-355, Seismic Design for Buildings and NAVFAC P-355.1, Seismic Evaluation of Supports for Existing Electrical-Mechanical Equipment and Utilities. Design should be consistent with the degree of structural safety for which buildings or facilities in earthquake areas are designed. When such construction is required in tropical and typhoon or hurricane areas, see data given in DM-11. Provide emergency generator unit(s) to supply essential loads for facilities in accordance with Section 10, of NAVFAC P-355. These units should be located within the building served.

2. INTERIOR DISTRIBUTION.

a. Luminaires. The luminaires, appurtenances, and outlet boxes need to be secured to prevent detachment when subjected to earthquake vibrations. Consider using swivel aliners for a pendant type installation. Luminaires should be provided with safety cable support of not less than No. 12 USS gage (5.64 mm^2) galvanized steel. Cable should not be secured to luminaire mounting plates, but to luminaire housings with suitable fittings. The upper end should be secured to structural members. Where possible, the upper end shall also be wrapped around structural members. Each support wire shall be capable of supporting four times the weight of the luminaire for which it provides seismic support. A minimum of two safety cables on diagonal corners are required for all recessed lighting fixtures. All installations shall be in accordance with Section 8 of NAVFAC P-355 and with NAVFAC P-355.1.

b. Conduit. Except as limited by DM-11, rigid or intermediate steel conduit should be considered for structural reasons, in lieu of electrical metallic tubing. When steel conduit is embedded in concrete slabs, the outside conduit diameter shall not exceed 1/5 of the slab thickness and conduits shall not be spaced closer than 5 diameters on centers, except at cabinet locations. At cabinet locations, design slab thickness shall be increased as necessary to prevent excessive loss of structural strength. Conduits and busways supported by hangers are subject to motions created by earthquakes, and sway bracing should be provided to prevent damage due to such motions.

c. Enclosures. Electrical equipment should not be housed in enclosures with snap-on covers that can be easily jarred loose. Insofar as practicable, all enclosures containing equipment vital to operations should be mounted in such a manner, that malfunctioning of equipment will not occur because of earthquake vibrations. See also criteria contained in Section 8 of NAVFAC P-355.

d. Seismic Withstand. Industry standards for seismic testing are in the developmental stage, except for IEEE 344, Seismic Qualification for Class IE Electric Equipment for Nuclear Power Generating

Stations. Equipment certified as qualified to meet typical damping values of this standard will have a cost premium, which can only be justified by systems whose loss would cause as much damage as would a significant release of radioactive material to the environment. However, IEEE 344 does provide a standard method of determining seismic withstand. In addition, NEMA SG-4, High-Voltage Power Circuit Breakers establishes a seismic withstand of 0.2g static for general-purpose medium- and high-voltage circuit breakers and 0.5g dynamic for definite-purpose circuit breakers. Definite-purpose circuit breakers are defined as circuit breakers installed in locations where seismic activity occurs frequently, and where a seismic withstand of above 0.2g static is desired. In most cases, equipment suitable for general use will be suitable in earthquake areas, if secured as required to meet local seismic requirements.

3. EXTERIOR DISTRIBUTION.

a. Overhead System. Unless permitted or required by other criteria or regulations, the electric power distribution and communications system should be installed overhead. When electric power is supplied by a public utility company only, their redundancy is no criteria for construction of an on-station distribution system as they have trained crews who can operate energized systems. On-station redundancy should relate to the need for reliability and availability. Where the station has the capability of connecting to an on-station electric generating plant construction of the on-station distribution system (vital electric power and communications) should also conform to the structural and mechanical design of the electric generating plant.

b. Underground System. Where underground duct systems are permitted or required, a determination should be made on whether or not they will contain electric power or communication lines required for vital operations. For those portions of the duct system containing lines for vital operations, consider the feasibility of providing reinforcing rods in the duct encasement and using rigid steel conduit in lieu of the types commonly used for underground ducts.

Appendix A

METRIC CONVERSION FACTORS

Appendix A METRIC CONVERSION FACTORS

CLASSIFIED LIST OF UNITS.

To Convert From	To	Multiply By
AREA		
ft^2	m^2	9.290E-02
in^2	cm^2	6.452E+00
kCM	mm^2	5.067E-01
LENGTH		
ft	km	3.048E-04
ft	m	3.048E-01
in	cm	2.540E+00
in	mm	2.540E-01
mile (statute)	km	1.609E+00
LIGHT		
footcandles	dekalux	1.076E+00
MASS		
oz	g	2.835E+01
lb	kg	4.536E-01
ton (short)	kg	9.072E+02
MASS PER UNIT AREA		
lb/ft^2	kg/m^2	4.882E+00
lb/in^2 (psi)	kg/m^2	7.031E+02
TEMPERATURE		
degree Fahrenheit	degree Celsius	$t°_C=(t°_F-32)/1.8$

NOTATION. Factors are written as a number greater than one and less than ten with three decimal places. This number is followed by the letter E (for exponent), a plus or minus symbol, and two digits which indicate the power of 10 by which the number must be multiplied to obtain the correct value. For example:

5.067E-01 is 5.067×10^{-1} or 0.5067

Similarly:

2.835E+01 is 2.835×10^{1} or 28.35

AMERICAN WIRE GAGE (AWG) CONVERSION.

AWG	kCM	mm^2
20	1.02	0.517
18	1.62	0.823
16	2.58	1.31
14	4.11	2.08
12	6.53	3.31
10	10.4	5.26
8	16.5	8.37
6	26.2	13.3
4	41.7	21.2
2	66.4	33.6
1	83.6	42.4
1/0	105.6	53.5
2/0	133.1	67.4
3/0	167.8	85.0
4/0	211.6	107.0

References

(Publications containing criteria cited in this manual)

ANSI or ANSI/IES Standards, American National Standards Institute, Inc., New York, NY 10018.

A85.1	Standard Practice for Protective Lighting
A117.1	Making Buildings and Facilities Accessible to, and Usable by the Physically Handicapped
C2	National Electrical Safety Code
RP-8	Standard Practice for Roadway Lighting

Beeman; Industrial Power Systems Handbook, latest edition, McGraw-Hill Book Company, Inc., New York, NY 10036.

DOD 4270.1-M, Department of Defense Construction Criteria Manual, Department of Defense. The Pentagon, Washington, D.C. 20301.

Federal Construction Guide Specifications, available at U.S. Naval Publications and Forms Center, Philadelphia, PA 19120. TWX: 710-670-1685, TELEX: 834295, AUTOVON telephone number 422-3321.

FCGS 16113	Underfloor Duct System
FCGS 16115	Underfloor Raceway System (Cellular Steel Floor)

IEEE Publications, Institute of Electrical and Electronic Engineers, New York, NY 10017.

No. 344	Seismic Qualifications of Class 1E Electric Equipment for Nuclear Power Generating Stations, Recommended Practice for
No. 446	Recommended Practice for Emergency and Standby Power Systems

IES Publications, Illuminating Engineering Society, New York, NY 10017, Lighting Handbook

NAVFACENGCOM Documents available at U.S. Naval Publications and Forms Center, Philadelphia, PA 19120. TWX: 710-670-1685, TELEX: 834295, AUTOVON telephone number 422-3321. The stock number is necessary for ordering these documents and should be requested from the NAVFACENGCOM Division in your area.

DM-3	Mechanical Engineering
DM-4.1	Preliminary Electrical Design Considerations
DM-4.2	Electric Power Distribution Systems
DM-4.3	Electric Switchgear and Relaying
DM-4.7	Wire Communication and Signal Systems
DM-8	Fire Protection Engineering
DM-11	Typhoon and Tropical Areas Engineering
DM-12	Electronic Facilities Engineering (to be issued)
P-355	Seismic Design for Buildings
P-355.1	Seismic Evaluation of Supports for Existing Electrical-Mechanical Equipment and Utilities
P-442	Economic Analysis Handbook
TS-16301	Underground Electrical Work
TS-16302	Overhead Electrical Work
TS-16335	Transformers, Substations and Switchgear, Exterior
TS-16402	Interior Wiring Systems
TS-16462	Pad Mounted Transformers
TS-16465	Interior Substations
TS-16475	Transformers, Substations and Switchgear, Interior
TS-16510	Lighting, Interior
TS-16530	Lighting, Exterior

National Electrical Code, NFPA No. 70, National Fire Protection Association, Boston, MA 02210.

NEMA Standards, National Electrical Manufacturers Association, New York, NY 10017.

FA-1	Outdoor Floodlighting Equipment

ICS Industrial Controls and Systems

SG-4 High-Voltage Power Circuit Breakers

OPNAV Instructions, Department of the Navy, Chief of Naval Operations, Washington, D.C. 20350.

INST 5510.45 U.S. Navy Physical Security Manual

Occupational Safety and Health Standards, (OSHA), Department of Labor, Bureau of Labor Standards, Wage and Labor Standards Administration, Washington, D.C. 20210.

UL Standards, Underwriters Laboratories, Inc., Chicago, IL 60611; Northbrook, IL 60062; Melville, Long Island, NY 11746; Santa Clara, CA 95050; Tampa, FL 33619.

57 Electric Lighting Fixtures

844 Electric Lighting Fixtures for Use in Hazardous Locations

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